Environment monitoring technical report for the SON cage fish culture site at Bugungu, Napoleon Gulf, northern Lake Victoria, March 2014

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EXECUTIVE SUMMARY

Source of the Nile Fish farm (SON) is located at Bugungu area in Napoleon Gulf, northern Lake Victoria. The proprietors of the farm and the National Fisheries Resources Research Institute (NaFIRRI) have an established collaborative arrangement where NaFIRRI provides technical back-stopping to enable quarterly environment monitoring of the cage site as a mandatory requirement of the National Environment Management Authority (NEMA). The agreed study areas are selected physical-chemical factors (water depth, water transparency/secchi depth, water temperature, dissolved oxygen, pH, conductivity, and nutrient status), algal community (including primary production), aquatic invertebrates (zooplankton and macro-benthos) and the fish community. This report presents field observations made during the first quarter (January-March) field survey undertaken during March 2014; along with scientific interpretation and discussion of the results in reference to possible impacts of the cage facility to the water environment quality and aquatic biota.

The SON cage study sites were coded as *'downstream of the cages'* (DSC), *'within the cages'* (WIC) and *'upstream of the cages'* (USC). Coordinate locations of the sampling points were determined with a GPS device. Physical-chemical parameters were measured in-situ with a pre-calibrated hydrolab at each site. A digital Echo Sounder was used to determine the total water depth. A black and white Secchi disc was used to determine water column transparency. Water samples for determination of nutrient and algal status were collected with a Van dorn sampler. Selected dissolved nutrients (SRP, NO_2-N, NH_4-N and TSS) were analyzed by spectrophotometric methods. Zooplankton community was sampled with a Nansen plankton net of 0.25m mouth opening and 60µm Nitex mesh. The macro-benthic community was sampled with a Ponar grab of 238cm^2 open jaw area. All samples were taken in triplicate at each sampling point. Invertebrate samples were microscopically examined for species composition, distribution and abundance patterns. The Fish community was sampled with three fleets of gill-nets of varying mesh sizes; fish caught were taxonomically identified and species numbers and weight recorded per site. Observations were also made on aspects of parasites, biology and ecology of the fishes.

The trend of depth profiles was comparable to previous observations i.e. USC > WC > DSC; with minor dissimilarities compared to previous surveys. Secchi depths varied between 1.6 and 1.8 meters across all the three study sites and this observation was comparable to previous records. Variation in turbidity (FTU) profiles between the three study sites were insignificant i.e. 3.4-3.8 at USC, 3.7-4.0 at WIC and 4.1-4.4 at DSC. Although marked differences in dissolved oxygen levels across the study sites (range: 4.3 - 7.6 mg/L), was recorded, there was no indication of influences from the fish cages at WIC. Mean water temperature ranged between narrow limits i.e. 26.2 to 26.6 ^{0}C; a normal range in tropical freshwater systems and suitable for biological processes of aquatic organisms. Electrical conductivity ranged between 110 and 120.0µScm^{-1} and was within what is normally observed in waters of Lake Victoria.

The highest value (0.0146mg/l) for soluble reactive phosphorus was recorded at the site with cages while the lowest (0.014mg/l) was at the downstream site. Nitrite-nitrogen levels increased from USC (0.0059mg/l) to DSC (0.0061mg/l) a trend that was comparable to that of the November 2013 survey. Similarly, Ammonia-nitrogen increased from 0.124mg/l at USC, to 0.147mg/l at WIC and 0.152mg/l at DSC; a trend was in contrast to observations made in November 2013. Total suspended solids (TSS) were generally low at all the three study sites ranging from 0.0034mg/l at WIC, 0.0039mg/l at USC to 0.0041mg/l at DSC.

Comparison of the results with both local (NEMA) and international standards showed that the concentrations of the investigated nutrients were below the maximum permissible limits and therefore not likely to significantly alter the natural water environment or to be harmful to aquatic biota.

Blue green algae, Green algae and Diatoms were the three broad taxonomic groups found at the three study sites. Algal species number generally increased from USC (19) through WIC (23) to DSC (32). Blue greens especially *Anabaena, Aphanocapsa, Planktolyngbya* and *Merismopedia* contributed the highest algal biomass (9000-11000 µg/L) and species richness (13-19 species) at all three study sites. Total algal wet biomass was higher at the site with cages (> 12000 µg/L) relative to the control and downstream sites (ca 11000 µg/L).

The zooplankton community was constituted by copepods, cladocerans and rotifers. Unlike the case in most previous surveys rotifers appear to have declined in species richness. The spatial distribution of zooplankton species richness lacked a depression at the site with cages that has been reported in most previous surveys. However, copepods maintained their numerical superiority at all sites with highest densities at the control site (USC).

The macro-benthos community was composed of 9 broad taxonomic groups: Bivalvia, gastropods (Mollusca/water snails), Ephemeroptera/mayfly nymphs, Trichoptera/caddisfly nymphs, Plecoptera/stonefly nymphs, Odonata/dragonfly nymphs, Diptera/two-winged fly larvae, Decapoda/freshwater shrimps and Annelida/fresh water worms. Four taxa: *Corbicula africana* (Bivalvia), *Bellamya* unicolor (Gastropoda), Oligochaetes (Annelida) and Chironomins (Diptera) were recovered in all the three study sites. Other taxa such as *Aspatheria* sp., *Caenis* sp., Heptageniids, *Ablabesmyia* sp., and *Cryptochironomus* sp. were rare and occurred only once in one of the study sites. The control site (USC) and the site with cages (WIC) supported the same number of taxa (15) but macro-benthos were poorly represented at the downstream site (8). Only one of the highly pollution-sensitive taxa (Ephemeroptera) was found at the site with fish cages while others such as Trichoptera, Plecoptera were not encountered at all in the study area. This observation was at variance with earlier SON reports showing absence of pollution-sensitive taxa at the site with fish cages. Dipterans and Annelida were nearly evenly distributed at the three study sites. Numerical abundance was highest at the control site (752 ind. m^{-2}), decreased to 607 ind. m^{-2} at the site with cage s and further to 542 ind. m^{-2} at the downstream site. Possible influence of the distribution of either macro-benthos taxa or numerical abundance by the fish cages at WIC was not evident from the survey results.

Fish community composition and catch rates were low compared to observations in the previous surveys probably as a result of loss of experimental gillnets at the site with cages (WIC). None of the fish caught was found to have ingested fish feeds administered to the cage fishes.

Overall, the November 2013 survey results indicate no (serious) interference of the SON cage fish operations on the water environment quality and fish stocks in the survey area

1.0 BACKGROUND

It is an obligatory requirement of the National Environment Management Authority (NEMA) of Uganda to undertake regular environment monitoring at all sites conceived to be sensitive to the natural environment. Fish cage culture in natural water bodies, which is currently being promoted in Uganda, is one such area that requires regular environment monitoring by a competent environment agency. Periodic environment monitoring surveys at the Source of the Nile (SON) cage fish farm, which were initiated in 2011 (quarterly) were sustained through 2012 (bi-annual), 2013 (quarterly) up to the present time (quarterly) aimed at tracking down possible negative developments resulting from the cage fish operations. The monitoring reports for the 2011, 2012 and 2013 surveys indicated no serious environmental perturbations at the cage fish farm save for some evidence of incipient pollution effects especially at the lower production levels (algae, zooplankton and macro-benthos) and these became apparent as the number of cages increased in the course of time (see 2011 and June & December 2012 SON survey reports). Suspected impacts included periodic algal blooms, reduced species diversity and numerical abundance of zooplankton, increase in abundance of pollution-tolerant macro-benthic forms (mollusks and dipteran larvae) and non-occurrence of the most pollution-sensitive macro-invertebrates (EPTs) at the transect with cages, WIC. These observations appear to suggest that as the number of cage units increase in any one culture site, there is a likelihood of development of negative impacts to both the natural water environment as well as sections of the aquatic biota. Environmental impacts may arise from bio-deposits of fish excretion, residual fish feeds, accumulation of faecal materials, pollutants etc, which may cause diurnal spells of low dissolved oxygen, algal blooms and many others (Nash (2001). Such localized stress factors, if persistent, can lead to negative changes in the in diversity, distribution and abundance patterns of some aquatic communities and environment quality, which if not checked, may affect fish production and productivity patterns in and around areas of fish cage operations.

The study site is located at Bugungu bay in the vicinity of the headwaters of the River Nile, where the Nile water current is already felt. The study transects are code-named WIC, USC, and DSC. WIC represents the transect where the fish cages are located. USC is the control/reference site and is located approximately 1 km upstream of the fish cage transect. DSC is located approximately 1 km downstream of the fish cages. The parameters investigated include water column depth profiles, Secchi depths (water transparency), selected physico-chemical parameters i.e. water temperature, dissolved oxygen, pH, electrical conductivity); nutrients status (Soluble Reactive Phosphorus– SRP, Nitrite nitrogen- NO_2-N, Ammonium-nitrogen- NH_4-N and Total suspended solids- TSS); algae, zooplankton, macro-benthos and fish communities.

The present report is the first quarter (Q1: January-March) report for the year 2014 and presents field observations made during the survey undertaken in March 2014. The report provides a scientific interpretation and discussion of the results with reference to possible impacts of the cage facilities to the water environment and the selected aquatic biota in and around the cage site. Survey conclusions are derived from the data generated and recommendations for cage operations in the lake are provided.

2.0 MATERIALS AND METHODS

The survey was conducted at Source of the Nile fish farm located in Napoleon gulf, northern Lake Victoria (Fig.1). Field measurements and sample collections were made at three points along each transect representing USC, WIC and DSC with respect to the location and areal spread of the fish cages. At each sampling point, thee replicate samples were taken for each parameter under investigation for the purpose of assessing variation in each parameter at each field site. Coordinate locations for each sample site were determined with a GPS device, recorded and used to prepare a site locations map (Figure 1).

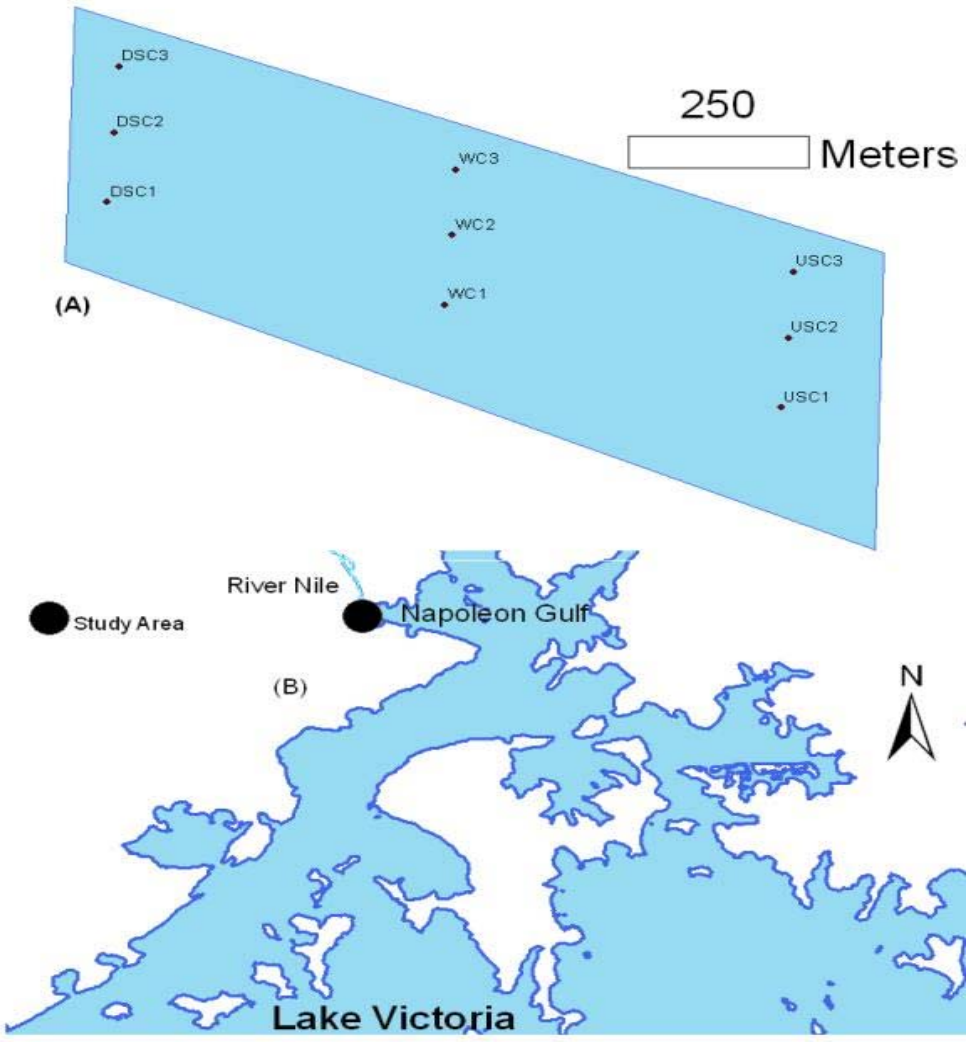

Figure 1. Map of the study area showing location of SON Cage Fish Farm and study areas: USC- upstream of the fish cages; WIC- within the fish cages and DSC- downstream of the fish cages, in Napoleon Gulf, northern Lake Victoria.

2.1 Depth profiles and water transparency

A digital Echo Sounder was used to determine the total water column depth at each sampling point. A black and white Secchi disc harnessed with a rope marked at 1-metre intervals was used to determine water column transparency.

2.2 Physical-chemical environment

Physical-chemical parameters (water column temperature, dissolved oxygen, pH and conductivity), were measured in-situ with a submersible multi-probe (CTD) containing a data logger and the data was down-loaded on to a computer for subsequent analysis.

2.3 Nutrient status

Water samples were collected in replicates with a Van Dorn sampler from the study sites and stored in clean, labeled plastic bottles. Sub-samples for dissolved nutrients i.e. soluble reactive phosphorus (SRP), ammonia-nitrogen (NH_3-N) and nitrite-nitrogen (NO_2-N) were filtered and analyzed by spectrophotometric methods following procedures by Stantoin et al. (1977). Separate water sub-samples were analyzed for total suspended solids (TSS).

2.4 Algal community

Water samples for the determination of algae, composition and biomass were collected using a three-litre a Van dorn sampler, placed in clean, labeled glass scintillation vials for laboratory analysis. Samples were analyzed using an inverted Microscope following methods by Mosille (1984) and (Hotzel & Croome 1998)

2.5 Micro-invertebrates (zooplankton) and Macro-invertebrates (macro-benthos)

The zooplankton community was sampled in triplicates at each sample point using a conical nitex plankton net of 0.25 metre mouth diameter and 60 µm mesh. Concentrated samples were placed in clean plastic bottles and fixed wit h 4% sugar- formalin. In the laboratory, samples were rinsed in tap water over a 50 µm nitex mesh and diluted to a suitable volume depending on the concentration of each sample. Series of 2ml, 2ml, and 5ml sub-samples were taken from a well agitated sample using a calibrated automatic bulb pipette, each introduced on to a plankton counting chamber and examined under an inverted microscope at x100 magnification. Individual organisms were taxonomically identified using zooplankton taxonomic manuals by Boxshall & Braide 1991; Korinek 1999; Korovchinsky 1992; Koste 1978. Members of each species were enumerated and recorded and used to generate composition, distribution and density data with respect to the study sites.

Macro-benthos community was sampled by taking sediment samples with a Ponar grab having open jaw area of 238cm^2, harnessed with a nylon rope marked at 1- metre intervals. Three grab hauls were taken from each sampling point and each kept separately for subsequent laboratory analysis. The bottom type and sediment texture were determined and described from visual observations and feel between two fingers. Each grab sample was concentrated, placed in clean, labeled sample bottle, and preserved with 5% formalin. In the laboratory, each sample was rinsed with tap water and spread on to a clean white plastic tray. Benthic organisms were sorted from the sediment using forceps and the sorted sample examined under a dissecting

binocular microscope at x 400 magnification. Taxonomically identification was done using manuals by Pennak (1953), Mandhal-Barth, (1954) and Epler (1995). All taxa were recorded and individuals of each taxon enumerated to generate data for community composition, distribution and abundance of the different taxa in reference to the study sites.

2.6 Fish community

Three fleets of gill-nets comprising panels of mesh sizes 1" to 5.5" in 0.5" increments, and 6 to 8 in 1" increments were set overnight at USC, WIC and DSC. The nets were set between 1800hr and 1900hr on the date of the field day and removed between 0600hr and 0700hr the following morning.

Fish caught by different nets in each fleet were sorted and identified as in Greenwood (1966). Some of the cichlid haplochromine fishes whose taxonomic identity could not be determined were in this survey, treated as a 'single species' group. For each fish species, the number, total weight (g) and individual total (TL) and standard (SL) lengths (cm) of the fish were measured and recorded. Fork length (FL) was measured for all fish species with forked caudal fins.

Biometric data (Total and Standard length, body weight, sex and gonad maturity state, stomach fullness and fat content) were determined and recorded for individual fishes. Fish guts were carefully removed placed in clean, labeled plastic sample bottles and preserved in 5% formalin for laboratory analysis of the diet as in Bagenal & Braun (1978). Fish specimens were also examined for any infection (parasitic or bacterial) both on the surface and within the gut cavity.

3. 0 RESULTS, INFERENCES AND DISCUSSION OF DATA

3.1 PHYSICAL-CHEMICAL PARAMETERS

3.1.1 Total depth (TD) and Secchi depth (SD)

Water column depth measurements taken across the three study sites indicated a range of 2.2-9.6 m at the upstream/control site (USC); 2.1-7.0 m at the site with cages (WIC) and 2.3-4.1 m at the site downstream (DSC) of the cages (Table 1). The trend of depth profiles was comparable to previous observations i.e. USC > WC > DSC; even though dissimilarities were noted with respect to depths at specific study points, probably due to variation in actual field points sampled. Secchi depths, a measure of water transparency, varied between 1.6 and 1.8 meters across the study sites, which was comparable to previous observations (1.5-1.8 metres). Comparable Secchi depth ranges across the study sites suggests no impacts on water transparency from the fish cages at WIC.

Table 1. Total and Secchi depths at the SON study sites, Napoleon gulf, March 2014. TD=total depth; SD=Secchi depth.

Site	TD (m)	Range	SD (m)	Range
USC 1	9.6	2.2 – 9.6	1.7	1.7 – 1.8
USC 2	9.0		1. 8	
USC 3	2.2		1.7	
WC 1	2.1	2.1 – 7.0	1.7	1.6 – 1.7
WC 2	6.1		1.6	
WC 3	7.0		1.6	
DSC 1	2.3	2.3 – 4.1	1.7	1.7 – 1.8
DSC 2	3.5		1.8	
DSC 3	4.1		1.7	

3.1.2 Turbidity profiles

Turbidity was nearly the same at USC (mean range: 3.4-3.8) and WIC (3.7-4.0) and increased slightly at DSC (4.1-4.4) but these variations (Fig. 2) were not significant, indicating no discernible influence from the cages at WIC.

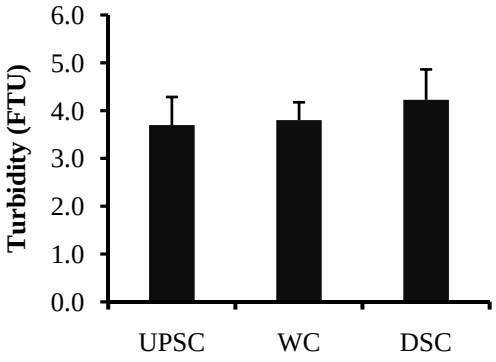

Figure 2. Trend in turbidity profiles at SON during the March 2014 period.

The turbidity ranges observed are considered low and harmless because turbidity levels up to 200 FTU are known to have negative impacts on fish through clogging of the gills and reduction in visibility (USEPA, 1986).

3.1.3 Dissolved Oxygen profiles

Mean dissolved oxygen ranged between 4.3 and 7.6 mg/L (Fig. 3). Lowest mean value was encountered at USC (2.8±1.28mg/L), thereafter increasing through WIC up to DSC (7.6 ± 0.155mg/L). This trend in dissolved oxygen however does not imply possible influences from the fish cages at WIC. Other factors such as increase in downstream flow rate of the water may have influenced the increasing dissolved oxygen concentrations across the study sites.

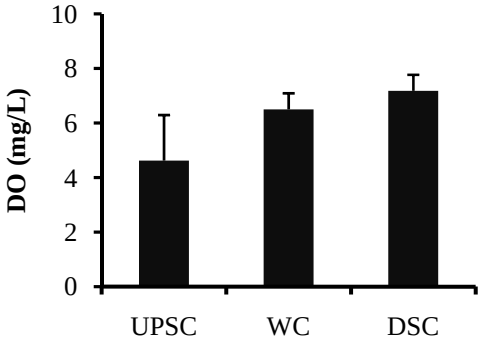

Figure 3. Trend in concentrations of dissolved oxygen across the study sites at SON, March 2014.

Observed mean dissolved oxygen concentrations indicate that there is sufficient oxygen for normal biological processes at the study site. The critical concentration for fish survival and breeding is 3mg/L.

3.1.4 Temperature profiles

Mean water temperature ranged between narrow limits i.e. 26.2 to 26.6 ^{0}C (Fig. 4). A gradual increase from USC through WIC up to the highest level at DSC was observed. However these variations were characterized by wide variations and did not, therefore, represent a significant temperature variation across the study sites. .

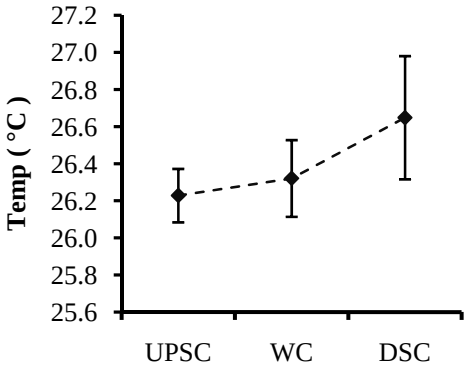

Figure 4. Trend in water temperature profiles across the study sites at SON, March 2014.

The temperature ranges observed across the study sites are considered not limiting for survival and growth of fish both in the cages and the wild.

3.1.5 pH

The pH varied within narrow ranges at the neutral level; between 7.01 ± 0.406 at USC and 7.31 ± 0.617 at DSC. Tilapia under cage culture does well at a pH range of between 6 and 8 range which is considered as suitable for cage culture fishery (Chapman, 2000). At pH far beyond the optimal range, the fish become stressed and this will affect their growth and food conversion rate hence impacting on their survival as well (Joseph *et al*, 1993). The observed range was therefore still within the suitable pH range for fish under cage conditions.

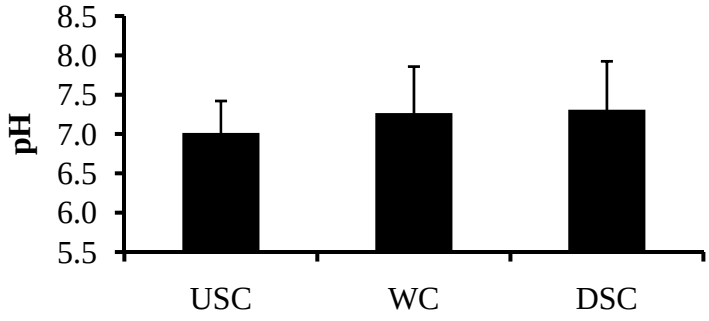

Figure 5. pH (mean ± stdev) across the three study transects

3.1.6 Conductivity

Conductivity (an indication of the presence of dissolved ions in a water column) ranged between 110 and 120.0µScm^{-1} and was within what is normally observed in Lake Victoria. There was thus no discernible influence on this parameter from the fish cages at WIC. Although the trend in conductivity showed an increase towards DSC (Fig. 6), this trend was probably influenced by the downstream flushing effect of the river water.

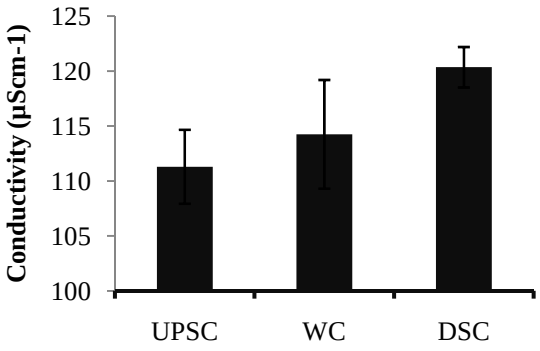

Figure 6. Trend in conductivity levels across the study sites at SON, March 2014.

All records were below 200 µScm^{-1} , which normally indicates ions being released into the water from sources such as wastewater influx.

3.2 NUTRIENT STATUS

3.2.1 Soluble reactive phosphorus (SRP)

The highest value (0.0146mg/l) for soluble reactive phosphorus was recorded at the site with cages while the lowest (0.014mg/l) was at the downstream site (Fig. 7). This distribution pattern was quite the opposite of the trend observed during the fourth quarter of 2013 when lowest values were obtained at the site with cages. It is possible that residual uneaten feeds may have occurred at WIC and the effect could have been reduced by downstream by dilution and likely by active algal uptake to contribute to high algal biomass observed at this site (see Fig. 11).

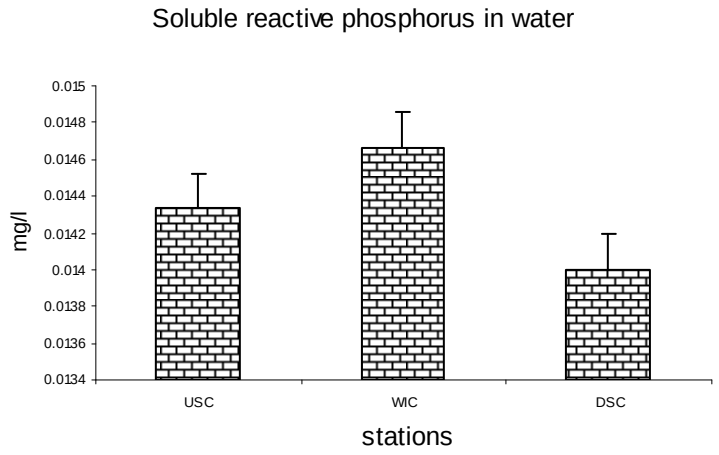

Figure 7. Trends of mean values of Soluble Reactive Phosphorus (SRP) at the 3 study sites at SON cage fish farm, March, 2014.

3.2.2 Nitrite-nitrogen (NO_2-N)

Nitrite-nitrogen levels increased gradually from USC (0.0059mg/l) to DSC (0.0061mg/l) (Fig.8); a trend that was comparable to the November 2013 survey. Nitrite is released as an intermediate product during the process of nitrification and denitrification (DWAF 1996; Bronmark & Hanson, 2005), but is quickly converted to other more stable nitrogen ions (Yves, 1998). High levels (exceeding 1.0mg/l) are toxic to fish, animals and humans, DWAF 1996. The slight variations of nitrites between the study sites suggested little or no impacts from the cage fish operations. The levels measured here were considered to be not detrimental to fish (and other biota) growth and development.

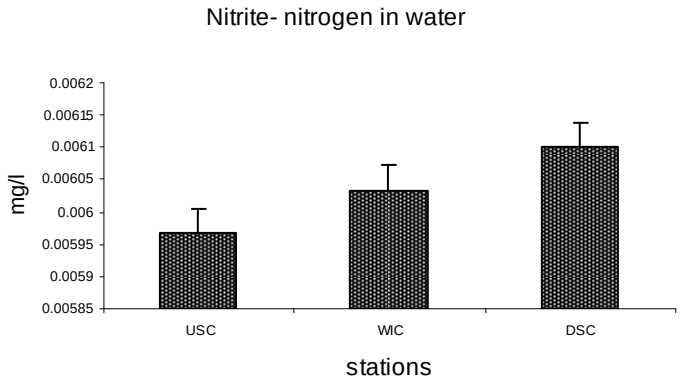

Figure 8. Trends in mean Nitrite-nitrogen values recorded at the study sites at SON cage fish farm, March, 2014.

3.2.3 Ammonium-nitrogen (NH_4-N)

Ammonia-nitrogen increased from 0.124mg/l at USC, to 0.147mg/l at WIC and 0.152mg/l at DSC (Fig. 9). The trend was nearly the opposite of observations made in November 2013 where a downstream reduction was recorded from USC through WIC to DSC. Rather elevated ammonia levels observed may have resulted from bacterial decomposition of organic materials such as dead aquatic plants, plankton and fish farm wastes i.e. fish excretion and uneaten fish feeds (Moss, 1998; Wetzel, 2001). Ammonia accumulation can be toxic and at a concentration of 12.3mg/l, sub lethal effects are manifested as reduction in growth rates and immunocompetence (EPA 1999).

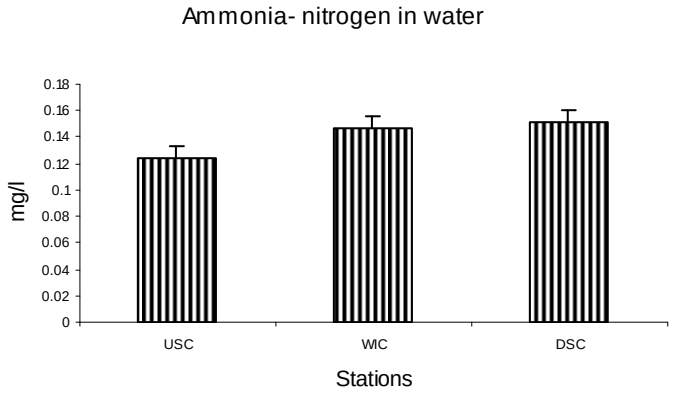

Figure 9. Trends in mean Ammonium-Nitrogen values recorded at the study sites at SON cage fish farm, March, 2014.

3.2.4 Total suspended solids (TSS)

Total suspended solids (TSS) were generally low at all three study sites ranging from 0.0034mg/l at WIC, 0.0039mg/l at USC to 0.0041mg/l at DSC (Fig. 10). The slight increase at DSC was not significant and may have been due to possible presence of uneaten feeds, faecal solids

in the water and eroded materials from the sediment due flushing effect downstream (Tlusty *et.al*. 2000).

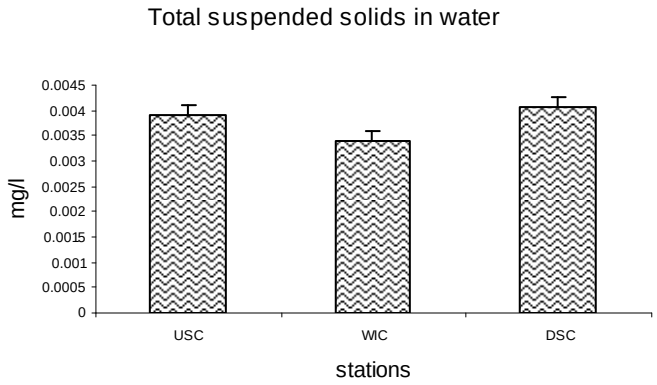

Figure 10. Variation of values of Total Suspended Solids (TSS) recorded at the study sites at SON, March, 2014.

The levels of all measured nutrient parameters were below those considered toxic to fish and other aquatic organisms (Boyd, 1996). SRP range (0.0146mg/l - 0.014mg/l) was less than the normal range of 0.1mg - 0.2mg/l **(**Sreenivasan, 1965) for the sustenance of phytoplankton density, which constitutes the natural food for many cichlid fishes. According to Joseph *et al.* (1993), ammonia (ionized ammonia (NH4+) is limited to 0.2 - 2.9mg/l for fish culture. The concentration of total suspended solids at all study sites was low (0.0034-0.0041mg/l) compared to < 25 mg/l recommended by Maitland (1990) for cage culture. Permissible levels by NEMA (1999) are: (ammonia - nitrogen: 10mg/l, nitrite-nitrogen: 2 – 20mg/l, soluble phosphorus: 5.0mg/l and total suspended solids: 100 mg/l). Thus the present results indicate that levels of the investigated nutrients were below the maximum permissible limits and confirm the conclusion that the nutrients levels were not likely to significantly alter the natural water environment or to be harmful to aquatic biota.

3.3 ALGAL COMMUNITY

3.3.1 Composition and biomass

Blue green algae, Green algae and Diatoms were the three broad taxonomic groups found in the samples taken from the three study sites (Figure 11). Blue greens contributed the highest algal biomass in all three sites. A*nabaena*, Aphanocapsa, Planktolyngbya *and Merismopedia* were the key algal genera among the blue green algae and these contributed to the high biomass (Table 1). Variation in wet blue-green algal biomass between the study sites was minimal (9000-11000 µg/L). However total algal wet biomass was higher at the site with cages (> 12000 µg/L) relative to the control and downstream sites (ca 11000 µg/L). As persistently recorded in previous surveys, there appeared to be an influence from the fish cages driving the high algal biomass at WIC relative to the control (USC) and downstream (DSC) sites. *Nitzschia* and *Synedra* and *Navicula* were the dominant genera in the diatom community.

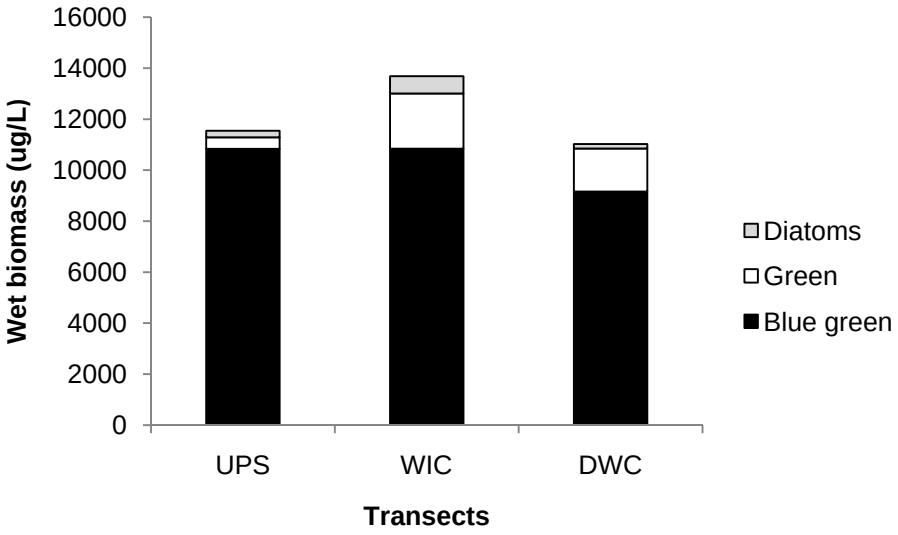

Figure 11. Estimates of wet biomas of major algal taxonomic groups at the three study sites at SON cage fish farm, March 2014

Table 2. Species checklist in the major taxonomic algal groups in the study sites, March, 2014**.**
Note: X denotes presence of the species

	Study sites		
Taxa:	USC	WIC	DSC
Blue green algae			
Planktolyngbya limnetica	X	X	X
Aphanocapsa spp	X		X
Aphanocapsa holistica	X		
Aphanocapsa delicatissima	X	X	X
Aphanocapsa elachista		X	x
Anabeanopsis tanganyikae			X
Merismopedia gluaca	X	X	X
Merismopedia teniussima			X
Microsystis aeruginosa		X	
Microsystis panniformis			x
Anabeana circinalis	X	X	X
Anabeana compacta		X	
Planktolyngbya tallingii	X	X	X
P.circumreta	X	X	X
P.contorta	X	X	X
P.undulata	X	X	
Romeria sp	X		
Chroococcus limneticus	X	X	X
Chroococcus turgidus	X		
Psuedoanabeana		x	X
Cyanodyction spp		x	
Ceolosphaerium spp		x	
Ceolomoron spp		x	x
Cylindrospermopsis africana		x	x
Cylindrospermopsis racibosskii			x
Glaucospira laxissima			x
Romeria spp			x
Green algae			
Monoraphidium contortum	X	X	
Kirchneriella sp	X		
Pediastrum simplex	X		X
Pediastrum tetras			X
Ceolastrum proboscideum		x	
Coelastrum costatum			x

Scenedesmus acuminatus		x	
Ankistrodesmus falcatus		x	X
Scenedesmus acuartus			x
Scenedesmus spp			x
Oosystis spp			x
Diatoms			
Synedra acus	X		X
Nitzschia acicularis	X	X	X
Navicula nyassensis			X
Cyclotella kutzingiana	X		
Navicula gastrum		X	X
Epethemia spp			X
Cyclotella kutzingiana			X

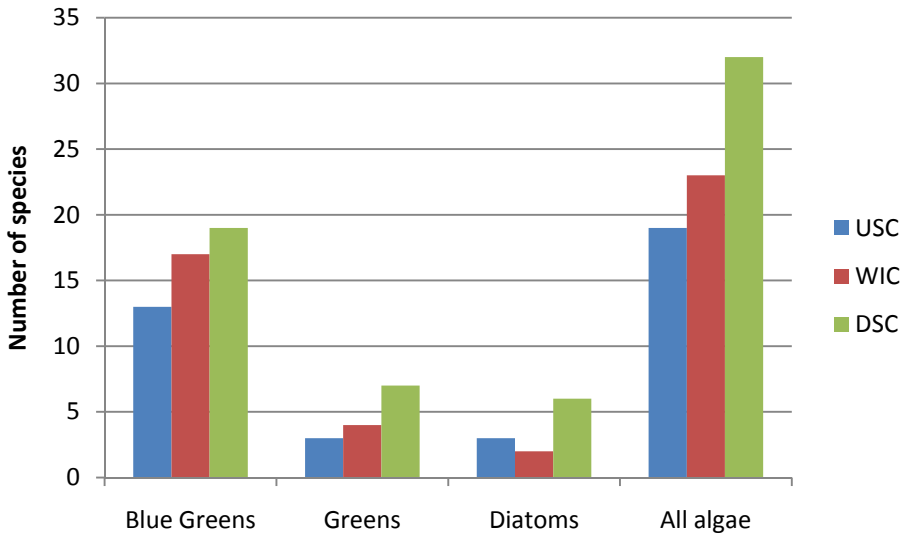

Figure 12. The distribution of algal species across study sites at SON cage fish farm, March 2014

The three algal groups were recovered at all three study site in varying species numbers. Blue green algae had the highest species numbers (13-19). The number of species for the different taxonomic groups increased from USC through WIC attaining peak a peak at the site downstream of the fish cages (Fig. 12). There was no evidence of possible influence of fish cages on the distribution of algal species across the study sites. Observed dominance of blue green algae has been a consistent feature of the monitoring surveys although species numbers have been changing over time and this time round, higher numbers were recorded downstream

(Fig. 11). Factors influencing temporal changes in algal species numbers are not well known although the observed changes appear to be natural and random.

3.4 ZOOPLANKTON COMMUNITY

3.4.1 Species composition, richness and distribution patterns

Total zooplankton species number recorded was 27 compared to 24 in the previous (November 2013) survey. Copepod species ranged between 3 and 5, cladocerans between 0 and 5 and rotifers between 2 and 6. Total species number was between 5 and 15 (Fig 13). Mean species numbers for the key taxonomic groups were 4, 2 and 4 for Copepoda, Cladocera and Rotifera respectively. In the current survey, the total species richness was highest at the control site (USC 3) where 15 species were recorded while lowest was found at the site downstream of the fish cages (DSC 1) with 5 species (Fig 13). The November 2013 and March 2014 surveys show a trend departing from the persistent depressions of species richness at the site with cages (WIC), previously reported in the SON quarterly reports of 2011 and 2012.

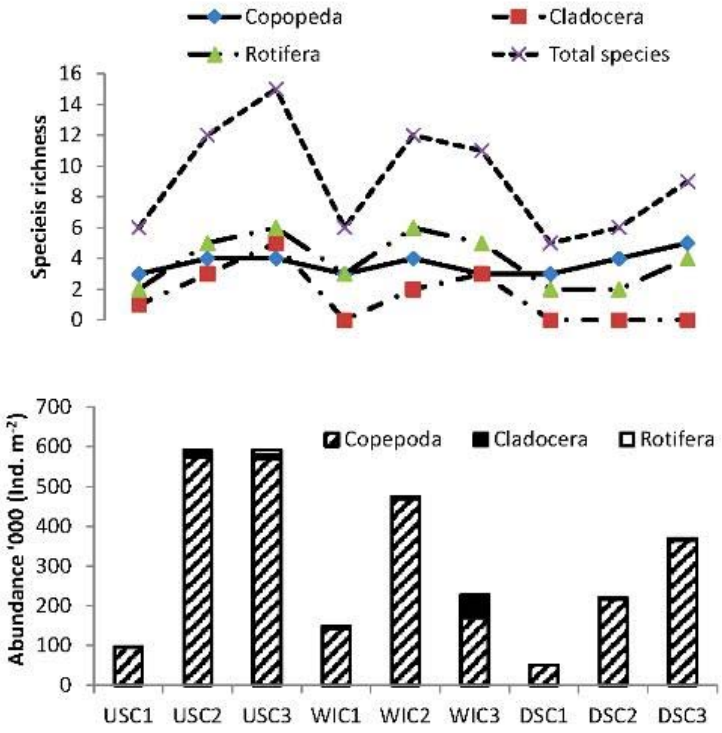

Figure 13. Zooplankton species richness and abundance (Ind. m^{-2}) patterns across study sites, at SON cage fish farm, March 2014. Notice difference in the Y-axis scales**.**

Variations of mean numerical abundance of zooplankton across the study sites indicate a downstream trend from the control site (USC) through the site with cages (WIC) to the downstream site (DSC) (Fig. 14). This trend does not provide clues to possible influence of the fish cages at WIC to the observed patterns of zooplankton abundance across the three study sites.

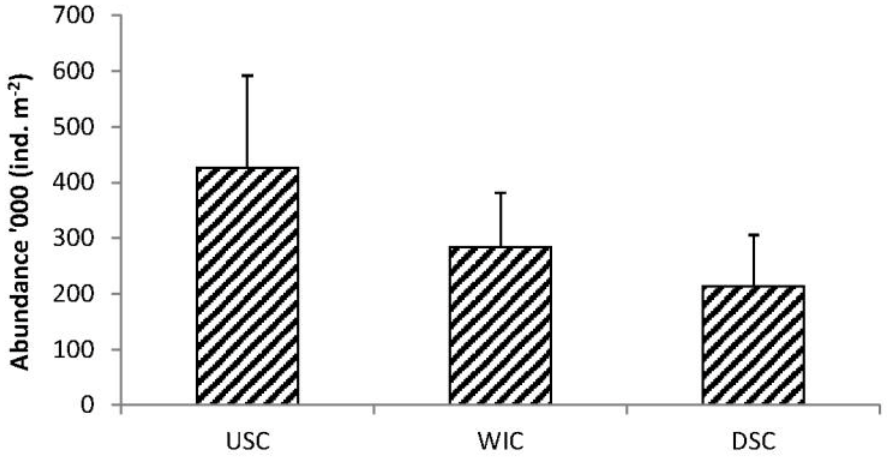

Figure 14. Mean abundance of zooplankton numbers across the study sites, March 2014

The most frequently encountered copepod species with >80% occurrence were: *Tropocyclops tenellus* and *Tropocyclops confinnis;* an observation which is consistent with previous surveys (Table 1) and this is an indication of relative stability of the zooplankton composition regardless of the presence of fish cages in the area.

Table 3. Zooplankton species composition, distribution and numerical abundance (ind. m^{-2}) across study sites at SON, March 2014

Sites	DSC1	DSC2	DSC3	WIC 1	WIC2	WIC3	USC1	USC2	USC3	Min	Max	Mean	%age Occurrence
Depth (metres)	1.5	3	3.5	2.1	5.5	6.5	2.1	8.5	8.5				
Copepoda:													
***Mesocyclops* sp.**									1,768	-	**1,768**	**196**	**11**
Tropocyclops confinnis	1,011	3,032	2,425	4,547	125	15,499		6,973	4,598	-	**15,499**	**4,245**	**89**
Thermocyclops decipiens						1,560				-	**1,560**	**173**	**11**
Thermocyclops emini		303	1,213							-	**1,213**	**168**	**22**
Thermocyclops neglectus	505		303		1,623		202	6,669		-	**6,669**	**1,034**	**56**
Thermocyclops oblongatus						2,497			15,915	-	**15,915**	**2,046**	**22**
Tropocyclopstenellus	4,547	5,154	7,579	3,032	1,872		2,829	21,827	14,501	-	**21,827**	**6,816**	**89**
Calanoid copepodites	2,526	3,335	11,823		1,748	8,946	3,032	11,217	10,257	-	**11,823**	**5,876**	**89**
Thermodiaptomus galeboides		1,516	909	3,638	374		808	909		-	**3,638**	**906**	**67**
Cyclopoid copepodite	3,284	35,166	44,563	23,949	40,622	141,471	14,956	47,292	58,710	**3,284**	**141,471**	**45,557**	**100**
Nauplus larvae	39,157	167,643	294,967	106,103	422,291		72,858	479,587	462,964	-	**479,587**	**227,286**	**89**
Cladocera:										-	-	-	-
Bosmina longirostris							202		707	-	**707**	**101**	**22**
Ceriodaphnia cornuta					303	208		5,457	3,537	-	**5,457**	**1,056**	**44**
Diaphnasoma excisum						1,352		1,819	2,476	-	**2,476**	**627**	**33**
Daphnia lumhortzi									707	-	**707**	**79**	**11**
Daphnia lumhortzi(helmeted)					125					-	**125**	**14**	**11**
Moina micrura						49,515		2,122	2,476	-	**49,515**	**6,013**	**33**
Rotifera:													
Brachionus angularis					874					-	**874**	**97**	**11**
Brachionus calyciflorus							606	303		-	**606**	**101**	**22**

Brachionus falcatus									1,061	-	**1,061**	**118**	**11**
***Euclanis* sp.**				303		1,248				-	**1,248**	**172**	**22**
Filinia opoliensis					499			3,032	1,415	-	**3,032**	**550**	**33**
***Hexathra* sp.**									2,122	-	**2,122**	**236**	**11**
Keratella cochlearis	253	1,516	909	3,032						-	**3,032**	**634**	**44**
Keratella tropica		2,122	2,122		749			303	2,122	-	**2,122**	**824**	**56**
Lecane bulla						1,144	1,011		4,951	-	**4,951**	**790**	**33**
Polyathra vulgaris.				3,941	624				2,122	-	**3,941**	**743**	**33**
Synchaeta pectinata						1,664				-	**1,664**	**185**	**11**
***Synchaeta* sp.**	253		1,516		874	936		1,516		-	**1,516**	**566**	**56**
Trichocerca cylindrica			1,213		1,872			1,819		-	**1,872**	**545**	**33**
Trichotria tetractis						1,560				-	**1,560**	**173**	**11**

The recent and ongoing expansion of the area with fish cages well beyond the original 'within cages' site and towards the control/upstream (USC) appears to be the main cause of differences in species richness and abundance trends between the present and previous surveys as reported in the 2011 SON reports (Mwebaza-Ndawula et al., 2013: In press). This reorganization can lead to the introduction and spreading of effects resulting from fish feeds in new areas. The expansion and stocking activity involves increase in stocked fish and fish feeds and subsequently use of larger volumes of water with greater dilution effects. The expansion appears to have covered a mainstream area of the Nile headwaters with greater flushing capacity that may quickly wash away any feed residues and metabolic wastes from the caged fish. This possibility is supported by occurrence of normal and favorable environmental conditions (see section on physico-chemical parameters and nutrient status in this report), which may mitigate stress factors as a result of fish cages. The persistent depression of species richness and numerical abundance which previously characterized the site with cages (WIC) seems to have shifted to area downstream of the cages (Figure 1 2); although the persistence of such shift needs to be established first.

Eutrophic water bodies have been shown to depict changes in phytoplankton productivity (i.e. development of algal blooms), fluctuations in pH, dissolved oxygen and conductivity levels, and a general decrease in aquatic biodiversity (Sekiranda *et al*., 2004, Tallberg *et al*., 1999, Cottenie *et al*., 2003, Hecky, 1993, Mazumder, 1994, Mugidde, 1993, Verschuren *et al*., 2002, Lungayia *et al*., 2001, Mavuti and Litterick, 1991). Changes in phytoplankton composition and productivity, are associated with structural changes in the food web and may affect the quality and quantity of phytoplankton composition and biomass *(Dodson et al*., 2000, Mugidde, 2004, Mwebaza-Ndawula, 1994, Tallberg *et al*., 1999, Cottingham, 1999), which in turn may alter zooplankton community structure; with tolerant zooplankton species and algal herbivores becoming dominant (Gosselain *et al*., 1998, Gowen *et al*., 1992, Steiner, 2003). The general decrease in zooplankton abundance could be a phenomenon associated with increase predation by stocked fish or other fish attracted to the area or an annual trend of abundance in the area.

3.5 Macro-benthic community

3.5.1 Composition and distribution The macro-benthos community was composed of 9 broad taxonomic groups: Bivalvia, gastropods (Mollusca/water snails), Ephemeroptera/mayfly nymps, Trichoptera/caddisfly nymphs, Plecoptera/ stonefly nymphs, Odonata dragonfly nymphs, Diptera/ twowinged fly larvae, Decapoda / freshwater shrimps and Annelida/ fresh water worms (Table 4). Only four taxa: *Corbicula africana* (Bivalvia), *Bellamya unicolor* (Gastropoda), Oligochaetes (Annelida) and Chironomins (Diptera) were recovered in all the three study sites; a trend which was similar to that in the November 2013 survey. These widely distributed taxa are considered to be ecologically important in that as potential food items for fish, they are assumed to be readily available to fish that feed on them and their occurrence at all the three study areas suggests that they may not be easily affected by the fish cage operations in the study area. On the other hand there were other taxa such as *Aspatheria* sp.*,Caenis* sp.*,* Heptageniids*, Ablabesmyia* sp.*,* and *Cryptochironomus* sp. that were rare and were only recovered once in one of the study sites. Such taxa may not be readily available to foraging fish and their utilization for fish nutrition may be limited.

Table 4. Composition/occurrence of macro-benthos taxa at three study sites the SON cage fish farm –June & December 2012 and May, September, November 2013 and March 2014. P denotes occurrence of the taxon.

Taxa	Areas sampled																	
	USC						WIC						DSC					
	Jun. 12	Dec. 12	May.13	Sep.13	Nov.13	Mar.14	Jun. 12	Dec. 12	May.13	Sep.13	Nov.13	Mar.14	Jun. 12	Dec. 12	May.13	Sep.13	Nov.13	Mar.14
Bivalvia																		
Byssanodonta parasitica	P		P	P		P	P		P	P		P		P		P		
Caelatura monceti			P		P	P	P		P	P					P			
Caelatura hauttecoeuri	P		P	P		P		P	P	P		P		P	P		P	
Corbicula africana	P		P	P	P	P	P	P	P	P	P	P		P	P	P	P	P
.Mutera bourgguignati								P		P				P				
Aspatheria sp.				P		P			P	P	P				P		P	
Sphaerium sp.									P									
Gastropoda																		
Bellamya unicolor	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Biomphalaria sp.						P			P			P			P			
Pila ovata												P						
Bulinus sp.	P			P				P	P	P				P		P		
Gabbia humerosa		P		P		P	P		P	P		P		P	P			
Melanoides tuberculata	P	P	P	P	P	P	P	P	P	P	P	P		P	P	P	P	
Anisus natalensis														P				
Ephemeroptera																		
Caenis sp.	P		P	P			P		P	P		P	P		P	P		
Ephemerella sp.			P															
Povilla adusta	P		P	P					P	P		P	P	P	P	P	P	P

Baetidae													P					
Leptophlebids	P		P	P									P					
Heptageniids												P	P					
Trichoptera																		
Leptocerids			P							P					P			
Psychomyiids	P		P	P						P					P	P		
Brachycentrids	P																	
Lemnophilids			P										P					
Plecoptera																		
Perlids			P															
Odonata																		
Libellulids										P					P			
Diptera																		
Ablabesmyia sp	P	P	P			P		P	P				P	P	P			
Chironomus sp.		P	P	P	P		P	P	P	P		P		P	P	P	P	P
Clinotanypus sp.							P		P	P		P						P
Cryptochironomus s				P		P			P	P						P		
Procladius sp.			P				P										P	
Tanypus sp		P						P		P				P	P	P	P	
Tanytarsus sp.				P	P				P	P	P		P	P		P	P	
Chironomins	P	P	P		P	P			P			P	P	P	P		P	P
Ceratopogonids								P	P	P				P	P	P	P	
Chaoborus sp.		P	P	P	P	P	P	P	P	P	P			P	P	P	P	P
Decapoda																		
Caridina nilotica			P							P	P							
Annelida																		
Hirudines	P		P	P			P			P				P	P			
Oligochaetes	P		P	P	P	P	P	P	P	P	P	P	P	P	P		P	P
Total no. of taxa	**15**	**8**	**22**	**18**	**9**	**15**	**13**	**12**	**22**	**25**	**8**	15	**11**	**19**	**21**	**14**	**14**	8

Bivalvia and Gastropoda supported nearly the same number of taxa at the control site (USC) and the site with fish cages (WIC) but were poorly represented at the downstream site (DSC) (Table 5). There was therefore no evidence of possible effects from the fish cages on the two molluscan taxa. Two taxa that are known to be sensitive to pollution (i.e. Trichoptera, Plecoptera) were not encountered in all three study sites. However the absence of these, together with two other taxa (Odonata and Decapoda), may not be attributed to impacts of fish cage operations in the area but probably to other environmental factors in the area. Ephemeroptera, one of the known pollution-sensitive macro-benthos, registered 3 taxa at the site with fish cages, 1 taxon at the downstream site and none at the control site. This observation is at variance with earlier records (see SON reports 2011) showing near absence of pollution- sensitive taxa at the site with fish cages and their recovery at the control and downstream sites. The on-going expansion of the cage area upstream beyond the original USC site appears to have covered areas of active Nile water low resulting in rapid wash down of any uneaten/residual feeds and metabolic products of the caged fish at WIC; thus ensuring good water quality conditions at this site. Dipterans and Annelida were nearly evenly distributed at the three study sites, indicating that there were no possible impacts on these two taxa from the fish cage operations in the area. A number of macro-benthos are used as indicators of water quality (Loren 1995). However the distribution patterns observed in the present survey suggest occurrence of favorable environmental conditions at the fish farm. Observations on selected water quality parameters in this survey, confirms the existence of good water quality conditions at the SON fish farm for aquatic biota.

Table 5. Number of macro-benthos taxa recovered at the three study sites at SON cage fish farm, March 2014

Macro-benthos broad taxonomic groups:	**USC**	**WIC**	**DSC**
Bivalvia	**5**	**3**	**1**
Gastropoda	**4**	**5**	**1**
Ephemeroptera	**0**	**3**	**1**
Trichoptera	**0**	**0**	**0**
Plecoptera	**0**	**0**	**0**
Odonata	**0**	**0**	**0**
Diptera	**4**	**3**	**4**
Decapoda	**0**	**0**	**0**
Annelida	**1**	**1**	**1**

3.5.2 Abundance patterns

Diptera, Gastropoda and Bivalvia were the more abundant taxa in the entire study area (Fig. 15) Bivalvia and Diptera were more abundant at the control site than at other sites. Gastropods depicted an even distribution of numerical densities across the study sites i.e. 191, 187, 177 ind. m^{-2} for USC, WIC and DSC respectively. Ephemeroptera and Annelida registered higher

abundances at site with cages (112 ind. m^{-2} and 93 ind. m^{-2} respectively). The overall distribution pattern indicated a gradual decrease of macro-benthos abundance from USC (752 ind. m^{-2}) through WIC (607 ind. m^{-2}) to the downstream site (542 ind. m^{-2}). The abundance patterns described here do not suggest possible influence of the fish cages on the occurrence and numerical abundance of the various taxa across the study sites.

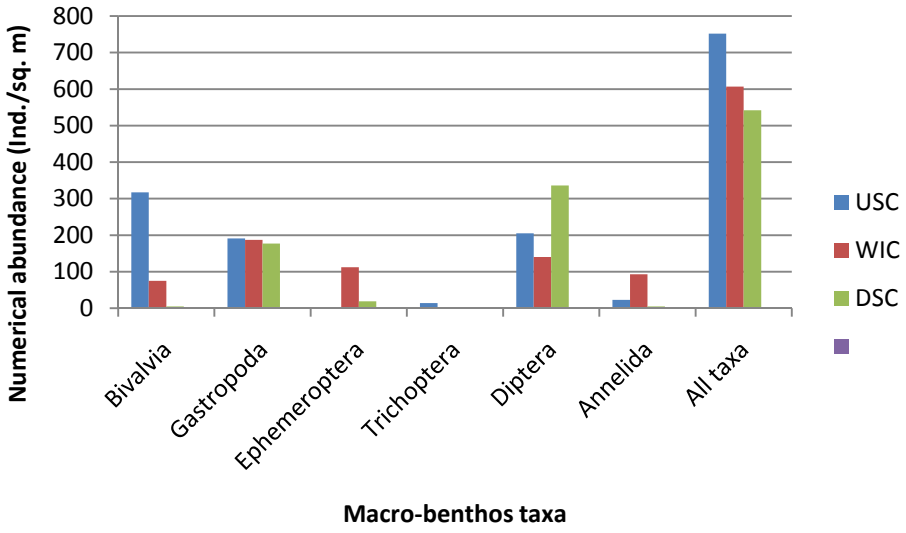

Figure 15. Numerical abundance of macro-benthos across the three study sites at SONcage fish farm, March 2014

Previous results have shown relatively higher densities of organisms at the site with cages (WIC) compared to USC and DSC. This trend has changed in the present and the last two surveys. In addition the most pollution-sensitive taxa (EPTs) have not been encountered at WIC, but the current results shows the occurrence of some ephemeropterans such as *Povilla adusta* and *Caenis* sp. at this site indicating generally good water quality conditions r and minimum or no impacts from the fish cages. Also the macro-benthos abundances in the three study areas generally low compared to earlier records.

3.6 FISH COMMUNITY

3.6.1 Background

Studies on ecological impacts of cage fish farming on fresh water ecosystems are few but several investigations have accrued to marine ecosystems (Naylor *et al*., 2000). Thus, impacts upon wild fish stock close to culture cages in freshwater systems are generally not well known. The fish rearing operations at SON fish farm involve keeping Nile tilapia fish in cages under high stocking densities and feeding them on artificial (pellet) feeds. Napoleon Gulf being a shallow bay at the headwaters of the River Nile in Lake Victoria, harbors a wide variety of wild fish species that are cherished by riparian human populations. The wild fishes living close to cages are presumed to be affected by activities associated with this method of fish farming. Cage fish farming may affect the presence, abundance, and diet of organisms in the vicinity of the farm (Carss, 1990; Dempster *et al.,* 2002). Floating structures including cages may act as Fish Attracting Devices (FADs) as most pelagic fishes are known to be strongly attracted to floating objects (Freon and Dagorn, 2000; Castro *et al.,* 2002). Attraction to cage sites may be largely due to plenty of food available for the cultured fishes (Bjordal and Skar, 1992). As such, other ecological interactions between cultured and wild fish may be possible. Wild fish may be instrumental in cleaning the environment close to the cages through consumption of excess un-eaten food left by culture fishes. Caged fish under crowded conditions is vulnerable to water-borne diseases and could infect wild fish or vice versa. While diseases breaking out among cultured fishes may be controlled through treatment, diseases in wild fishes stocks may spread unabated and in severe cases can affect yields of a capture fishery.

3.6.2 Fish Catch composition

A total of 5 fish species, including haplochromines (Nkejje) as a single species group, were recorded in the vicinity of the cages (Table 6). Haplochromines dominated the catch by numbers (84.6%). However, by weight *Clarias gariepinus* was the most dominant fish species (66.2%). Other fishes caught were *Lates niloticus*, *Synodontis afrofischeri*, and *Mormyrus kannume*. The lowest fish species number (1 species = *C. gariepinus*) was recorded at the site downstream of the cages (DSC) while the highest species number (4 species) was recorded Upstream of the cage area. No fish catch was obtained from the site with cages (WIC) because the set gillnets were stolen overnight! Highest numerical abundance (97.4%) was registered upstream (USC) while highest fish biomass was recorded downstream of the cages (66.2%).

Table 6. Fish species community composition at two study sites from the SON cage site, March 2014

Site	Downstream (DSC)		Upstream (USC)		Overall	
Species	% No	% Wt	% No	% Wt	% No	% Wt
Lates niloticus	0	0	2.6	46.8	2.6	15.8
Clarias gariepinus	100	100	0	0	2.6	66.2
Synodontis afrofischeri	0	0	5.3	5.3	5.1	1.8
Mormyrus kannume	0	0	5.3	5.3	5.1	10.0
Haplochromines	0	0	86.8	18.3	84.6	6.2

3.6.3 Haplochromines

Two species of haplochromines, belonging to one genus, *Astatotilapia* were obtained from the Upstream site (**Table 7**) only. The species were *Astatotilapia* sp. and *Astatotilapia* "purple dorsum". *Astatatotilapia* sp. was dominant both by numbers (96.9%) and by weight (91.3%)

Table 7: Catch rates (by number and weight) of haplochromine species recorded from the SON cage site, March 2014

Site	Upstream (DSC)	
Species	By Numbers	By Wt (g)
Astatotilapia sp	8	66
Astatotilapia "purple dorsum"	0.3	6.3
A11	**8.3**	**72.3**

The overall catch rate for haplochromines from two sites in March 2014 was 2.6 fish/net/night and 24.1g/net/night (compared to 28.1fishes/net/night and 404.2g/net/night recorded in previous survey of November 2013). Catch rates were highest for *Astatotilapia* sp. both by number (2.7 fishes/net/night) and weight (24.1g/net/night)

3.6.4 Catch rates/Biomass estimates

As a measure of standing biomass, catch rates i.e. catch per net per night was used to indicate relative abundance of fish species. To analyze gillnet performance; the nets and thus fish species were grouped into three categories. Category (A) consisted of fishes that grow to a small adult size and are caught by nets of up to 2.5" stretched mesh. Category (B) consisted of fish that could be retained by nets of up to 4.5" while category (C) was of large fish species capable of being caught in all the nets set.

In terms of numbers, catch rates were highest Upstream of the cages with 2.9 fish per net while by weight, catch rate was highest downstream with 235.8g per net (**Table 8**). Overall mean

catch rates from the two study sites were 1 fish/net/night and 120g/net/night as (compared to 8.8 fish/net/night and 165.5g/net/night recorded in the previous survey, November 2013).

Table 8. Catch rates (numbers and weight) of fish species recorded from the SON cage site, March 2014

Site	**Downstream (DSC)**		**Upstream (USC)**		**All sites**	
Species	Nos.	Wt (g)	Nos.	Wt (g)	Nos.	Wt (g)
L. niloticus	0	0	0.2	6.5	0.03	18.9
C. gariepinus	0.1	238.5	0	0	0.03	79.5
S. afrofischeri	0	0	0.3	10.4	0.1	3.5
M. kannume	0	0	0.3	58.5	0.1	19.5
Haplochromines	0	0	8.3	72.3	2.7	24.1
All species	0.1	235.8	2.9	121.5	1	120

3.6.5 Biology of common fish species

Basic biology of common fish species caught from the cage area in all sites sampled, during March 2014 is summarized in **Table 9.**

Table 9: Basic biological parameters of fish species caught at SON fish cage farm, March 2014

Species	**Site**	**No. examined**	**Size range (cmTL)**	**% mature**	**Food type**
Lates niloticus	Upstream (USC)	1	40.6	Nil	Fish
Synodontis afrofischeri	Upstream	2	14.2 – 15.5	All mature	Chironomids, Povilla
Mormyrus kannume	Upstream	2	36.0 – 20.0	Nil	Chironomids,
Clarias gariepinus	Downstream (DSC)	1	70.0	Mature	Empty
Astatotilapia sp.	Upstream	32	7.7 – 9.7	All mature	Chironomids, Chaoborids

Fish catch rates by number were lower in March 2014 (1fish/net/night) than in November 2013 (8.8 fish/net/night). The lower catch rate was due to no catch obtained in the experimental gillnets at WIC. All the fishes examined did not show any of the foods supplied/fed to the farmed fish.

3.6.6 Fish community summary

- Overall mean catch rates during the period March 2014 were calculated at 1fish/net/night and 120g/net/night as compared to 8.8 fish and 165.6g recorded in November 2013; indicating a drastic drop probably associated with loss of all nets (and fish samples!) set at the site with fish cages (WIC).

- Among the haplochromines, overall catch rate in March 2014 was lower at 2.7 fish/net/night and 24.1g/net/night as compared to 28.1 fish and 404.2g per net per night recorded in the previous survey of November 2013

- Two species of haplochromines were recorded in the vicinity of the cages in March 2014; compared to six species recorded in November 2013

- Fish species diversity was highest (4) Upstream (USC) and lowest (1) Downstream (DSC) the cages. Catch rates by number were highest upstream of the cage site while by weight they were highest at the downstream site

- Haplochromine (2 species) were only recorded from the upstream site. Apart from *Lates niloticus*, and *Mormyrus kannume*, all the fish species examined during March 2014 were mature and breeding.

- The diet of fishes encountered consisted of fish and insects, which are known natural foods of the species caught. No fish gut contained food fed to fish in the cages.

- No infection by fish parasites was noticed on the fishes caught during the survey of March 2014

4.0 General Conclusions

1. There was no indication of deteriorating water quality in the study area with respect to the studied physico-chemical parameters.
2. The observed temperature, oxygen, pH, conductivity and turbidity ranges all pointed to normal conditions naturally occurring in fresh water environments.

3. Observations on nutrient status in the study area showed that the different nutrient species were below the maximum permissible limits by NEMA and other environmental standards
4. There is continued dominance of blue green algae and this feature is common around inshore areas in Lake Victoria.
5. The high algal biomass at the site with fish cages (WIC) relative to the other two study sites is a persistent feature reported in previous reports and indicates possible influence of the fish cages upon the phytoplankton community although inter-site differences were rather small.
6. Zooplankton composition and diversity did not show changes in comparison to observations in the baseline study and previous monitoring reports, indicating relative stability of the community despite introduction of fish cages in the area
7. Previously reported low zooplankton species diversity at the site with cages (WIC) was this time not seen.
8. The recovery of an EPT, *Povilla adusta* at the site with fish cages (WIC) is in agreement with the November 2013 survey report but is a very unusual development as EPTs have been not regularly been encountered at WIC in most previous surveys.
9. The on-going expansion of area covered by fish cages well beyond the original USC/control site and into the mainstream Nile current may have mitigated some conceived stress factors as a result of fish cages, hence changes in some of the previous observations regarding zooplankton diversity and recovery of EPTs at WIC.
10. Abnormally low fish catch rates and fish diversity observed was probably associated with loss of all gillnets (and fish samples!) set at the site with fish cages (WIC)**.**

    The overall conclusion is that so far there is no clear- cut evidence to suggest that fish cages at the SON cage fish farm have negative impacts on the environment and aquatic biota in the area.

5.0 Recommendations

1. Observed changes especially in the distribution and abundance patterns of zooplankton and macro-benthos require further field observations to establish the consistency of the current trends or not.
2. There is need to take measures to prevent further gillnet and fish data loss that happened during the present survey

6.0 REFERENCES

Bagenal, T. and E. Braum (1978). Methods of assessment of fish production in freshwaters. IBP Handbook 3. Blackwell Scientific Publications, Oxford. (3rd edition).

Bjordal, A., & Skar, A.B. 1992. Tagging of saithe (*Pollachius virens* L.) at a Norwegian fish farm: preliminary results on migrations. *ICES Council Meeting Papers 1992/G* 35.

Boxshall, G.A. & E.I. Braide (1991). The freshwater cyclopoid copepods of Nigeria with an illustrated key to all species. Bull.Br. Mus. Nat. Hist. (Zool) 57: 185-212.

Boyd, C.E. (1996). Environmental Impact Statement for Ecologically Responsible Shrimp Farming Project in the Rufigi delta Tanzania prepared for the African Fishing Company LTD Dar es salaam, 112

Bronmark, C. & Hansson. 2005. The Biology of lakes and Ponds. Oxford University Press. Oxford.

Carss, D.N. (1990). Concentration of wild fish and escaped fishes immediately adjacent to fish farm cages. *Aquaculture* 90:29-40.

Castro, J.J., Santiago, J.A., & Santana-Ortega, A.T. (2002. A general theory on fish aggregation to floating objects: an alternative to the meeting point hypothesis. *Reviews in Fish Biology and Fisheries* 11:255-277.

Cottenie, K., Michels, E., Nuytten, N. & Meester, L. D. (2003) Zooplankton metacommunity structure: Regional vs Local processes in highly interconnected ponds. *Ecological Society of America***,** 991-100.

Cottingham, K. L. (1999) Nutrients and zooplankton as multiple stressors of phytoplankton communities: Evidence from size structure. Limnology Oceanography, 44, 810-827.

Dempster, T., Sanchez-Jerez, P., Bayle-Sempere, T., Gimenez-Casalduero, F., & Valle, C. (2002). Attraction of wild fish to sea cage fish farms in the south-western Mediterranean Sea: spatial and short-term temporal variability. *Marine Ecology Progress Series* 242:237-252.

Dodson, S. I., Arnott, S. E. & Cottingham, C. L. (2000) The relationship in lake communities between primary productivity and species richness. *Ecology,* 81**,** 2662-2679.

DWAF, (1996). South African Water Quality Guidelines. Volume 7: Aquatic Ecosystems, Pretoria.

EPA, (1999). Introduction to the National Pretreatment Program EPA-833-B=98-002. U.S. Environmental Protection Agency, Washington, D.C.

Epler, J.H (1995). Identification Manual for Chironomide of Florida Revised Edition.

Freon, P., & Dagorn, L. 2000. Review of fish associative behaviour: towards a generalisation of the meeting point hypothesis. *Reviews in Fish Biology and Fisheries* 10:183-207.

Greenwood, P.H. (1966). *The Fishes of Uganda.* The Uganda society, Kampala. (2nd ed,). 131 pp.

Gosselain, V., Viroux, L. & DEscy, J. P. (1998) Can a community of small-bodied grazers control phytoplankton in rivers? *Freshwater Biology,* 39**,** 9-24.

Gowen, R. J., Tett, P. & Jones, K. J. (1992) Predicting marine eutrophication: the yield of chlorophyll from nitrogen in Scottish coastal waters. *Marine Ecology Progress Series,* 85**,** 153-161.

Hecky, R. E. (1993). The eutrophication of Lake Victoria. *Verhandlungen des Internationalen Verein Limnologie,* 25**,** 39-48.

Hotzel, G. and R. Croome., (1998). Aphytoplankton Methods Manual for Australian Rivers.

Joseph K. B., Richard W. S. ,Daniel E. T. (1993). An introduction to water chemistry in freshwater aquaculture, University of Massachusetts Dartmouth North Dartmouth Massachusetts 02747. NRAC Fact Sheet No. 170-1993.

Korinek, V. (1999). A guide to limnetic species of Cladocera of African Inland waters (Crustacea, Branchiopoda). Occasional publication No. 1. The International Association of Theoretical and Applied Limnology. SIL.

Korovchinsky, N.M. (1992). Guidelines to the identification of the microinvertebrates of the continental waters of the world. Dididae and Holopedidae (Crustacea: Daphniiformes). SBP Academic Publishing . The Hague, The Netherlands.

Koste, W. (1978). Rotatoria. Die Radtiere Mitteleuropars. Ein Bestimmungwerk, begrundet von MaxVoig. Uberrordnung Monogononta. Gebruder Borntraeger, Berlin, Sturtgart.

Loren L. K. 1995. Save Our Streams- Monitor's Guide to Aquqtic Macroinvertebrates , 2nd edition. Izaak Walton League of America.

Lungayia, H., Sitoki, L. & Kenyanya, M. (2001). The nutrient enrichment of Lake Victoria (Kenya waters). *Hydrobiologia springer Netherlands,* 458**,** 75 - 82.

Lungayia, H., Sitoki, L. & Kenyanya, M. (2001). The nutrient enrichment of Lake Victoria (Kenya waters). *Hydrobiologia springer Netherlands,* 458**,** 75 - 82.

Maitland, P.S. (1990) Biology of Fresh Waters.. Chapman and Hal l.USA. 269pp.

Mandahl-Barth, G. (1954). The Freshwater Mollusks of Uganda and adjacent Territories.

Mavuti, K. M. & Litterick, M. R. (1991) Composition, distribution and ecological role of zooplankton community in Lake Victoria, Kenya waters. *Verhandlungen des Internationalen Verein Limnologie,* 24**,** 1117 - 1122.

Mazumder, A. (1994) Patterns of algal biomass in dominant odd-link vs even-link lake ecosystems. *Ecology,* 75**,** 1141-1149.

O.Mosille., (1984). Phytoplankton species of Lake Victoria.

Moss, B. (1998). Ecology of Fresh Waters: man and medium, past to future. Third Edition. Blackwell Science Ltd. Oxford.

Mugidde, R. (1993) The increase in phytoplankton primary productivity and biomass in Lake Victoria (Uganda). *Verhandlungen des Internationalen Verein Limnologie,* 25**,** 846-849.

Mugidde, R. (2004) Changes in phytoplankton communities and primary production. IN BALIRWA, J. S., MUGIDDE, R. & OGUTU-OHWAYO, R. (Eds.) *Challenges for Management of the Fisheries Resources, Biodiversity and Environment of Lake Victoria.* First ed., Fisheries Resources Research Institute.

Mwebaza-Ndawula, V. Kiggundu, G. Magezi and J. Naluwairo, (In press). Influence of fish cage culture practices on nutrients, algae and zooplankton in northern Lake Victoria, Uganda. African Journal of Ecology.

Mwebaza-Ndawula, L. (1994) Changes in relative abundance of zooplankton in northern Lake Victoria, East Africa. *Hydrobiologia,* 272**,** 256-264.

Nash, C.E.(Editor). 2001. The net-pen salmon farming industry in the Pacific Northwest. U.S. Dept. of Commerce., NOAA Tech. Memo. NMFS-NWFSC-46.

Naylor, R., Goldburg, R., Primavera, J., Kautsky, N., Beveridge, M., Clay, C., Folke, C., Lubchenco, J., Mooney, H., & Troell, M. (2000). Effects of aquaculture on world fish supplies. *Nature* 405:1017-1024.

Pennak, R. W. (1953) *Fresh-water invertebrates of the United States,* New York, John Wiley & Sons.

Sekiranda, S.B.K., J. Okot-Okumu, F.W.B. Bugenyi, L.M. Ndawula and P. Gandhi (2004). Variation in composition of macro-benthic invertebrates as an indication of water quality status in three bays in Lake Victoria. Ug. J. Agr. Sci. 9:396-411.

Sreenivasan, A. (1965). Limnology and productivity of tropical upland impoundments in Nilgiris, Madras state India. Phycos., 7(1). 146-160.

M. P. Stainton, M.J. Capel and F.A .J. Armstrong, (1977).The Chemical Analysis of Fresh Water, 2nded. Fish. Mar. Serv. Misc. Spec. Publ. 25:166p

Steiner, C. F. (2003) Keystone predator effects and grazer control of planktonic primary production. *OIKOS,* 101**,** 569-577.

Tallberg, P., Horppila, J., Vaisanen, A. & Nurminen, L. (1999) Seasonal succession of phytoplankton and zooplankton along a trophic gradient in a eutrophic lake implications for food web management. *Hydrobiologia,* 412**,** 81-94.

The National Environmental (Standards for Discharge of Effluent into Water or Land) Regulations S. I. No. 5/1999 (Under Section 26 and 107 of the National Environmental Act, cap 153)

Tlusty, M.F., Snook, K., Pepper, V.A. & Anderson, M.R. (2000). The potential for soluble and transport loss of particulate aquaculture wastes. Aquaculture Research 31: 745-755

USEPA, (1986). Quality criteria for water. EPA#440/5-86-001.

Verschuren, D., Johnson, T. C., Kling, H. J., Edgington, D. N., Leavitt, P. R., Brown, E. T., Talbot, M. R. & Hecky, R. E. (2002) History and timing of human impact on Lake Victoria, East Africa. *The Royal Society,* 269**,** 289-294.

Wetzel, G.R. (2001). Limnology. Lake and River Ecosystems. Third Edition. Academic Press. San Diego.

Yves C. (1998). Nitrate uptake, nitrite release and uptake and new production estimates. Marine Ecology Progress Series, Vol.b171: 293-301